

Traits and genotypes may predict the successful training of drug detection dogs

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Abstract

In Japan, approximately 30% of dogs that enter training programs to become drug detection dogs successfully complete training. To clarify factors related to the aptitude of drug detection dogs and develop an assessment tool, we evaluated genotypes and behavioural traits of 197 candidate dogs. The behavioural traits were evaluated within 2 weeks from the start of training and included *general activity*, *obedience training*, *concentration*, *affection demand*, *aggression toward dogs*, *anxiety*, and *interest in target*. Principal components analysis of these ratings yielded two components: Desire for Work and Distractibility. Desire for Work was significantly related to successful completion of training ($P < 0.001$). Since 93.3% of dogs that passed training and 53.3% of the dogs that failed training had Desire for Work scores of 45 or higher, we will be able to reject about half of inappropriate dogs before 3 months of training by adopting this cut-off point. We also surveyed eight polymorphic regions of four genes that have been related to human personality dimensions. Genotypes were not related to whether dogs passed, but there was a weak relationship between Distractibility and a *5HTT* haplotype ($P < 0.05$).

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1. Introduction

The dog (*Canis familiaris*) is the oldest domesticated animal. Domestication is estimated to have taken place between 12,000 and 14,000 years ago (Clutton-Brock, 1995), though some estimates suggest domestication occurred as early as 15,000 years ago (Savolainen et al., 2002). From ancient times dogs have served as hunting dogs, guard dogs, herding dogs, army dogs, food, pets, and other roles. Today, some dogs play an active role in our society as guide dogs, drug detection dogs, and rescue dogs.

Previous studies have attempted to develop aptitude measures that are related to successful training of dogs for certain tasks. One study (Wilsson and Sundgren, 1997) showed that, compared to German Shepherds that were not suitable for work as police dogs, German Shepherds that were suitable were rated as higher in ‘courage’, ‘hardiness’, ‘prey drive’, ‘defense drive’, and ‘nerve stability’. In another study Rooney and Bradshaw (2004) showed breed differences in behavioural attributes that are desirable for dogs used to locate explosives, weapons, or drugs; English Springer Spaniels and Border Collies scored significantly closer to ideal levels than Labrador Retrievers and cross breeds for ‘agility’, ‘tendency to be distracted when searching’, ‘independence—ability to work without constant guidance’, ‘stamina’, and ‘motivation to obtain food’.

Studies assessing aptitude for becoming guide dogs have also been reported by Serpell and Hsu (2001) who asked breeders to rate puppies on a questionnaire that later predicted whether dogs would be suitable guide dogs. In addition, Kikkawa et al. (2005) reported that salivary secretory immunoglobulin A (sIgA) concentration, a marker of psychological stress in humans, predicted whether dogs were suitable as guide dogs.

It is also likely that genetic factors influence behavioural traits in dogs and aptitude for various roles. There are more than 400 canine breeds differing in external morphology and behaviour (Hart and Hart, 1985; Bradshaw et al., 1996; Svartberg, 2006), suggesting that genes underlie these morphological and physiological traits (Saetre et al., 2006). Because some breeds are known to be better suited as working dogs, it is possible that genetic differences among breeds underlie this aptitude. In humans, several candidate genes have been reported to have association between their polymorphisms and personality (Catalano et al., 1993; Rubinow and Schmidt, 1996; Ebstein et al., 1997; Reif and Lesch, 2003). Although many studies have examined personality and temperament in dogs (Jones and Gosling, 2005), the genetic contribution to behavioural traits in dogs has not been clarified. We therefore surveyed genes that have been related to human personality dimensions.

Among the genes, the polymorphism of the dopamine receptor D4 gene (*DRD4*) has been related to novelty seeking (Ebstein et al., 1997). In dogs, previous studies have reported the existence of polymorphisms of exon1 (Ito et al., 2004), exon3 (Niimi et al., 1999), and intron2 (Nara et al., 2005) of *DRD4*. In addition, these studies demonstrated that aggression was higher in breeds in which the frequency of long alleles was high than in breeds where the frequency of short alleles was high (Ito et al., 2004).

The serotonin transporter 1A (*5HTT1A*) and serotonin transporter (*5HTT*) genes play a role in anxiety through the signal transduction of serotonin (Lesch et al., 1996; Reif and Lesch, 2003). In dogs, substitution at A808C (Lys/Gln) in *5HTT1A* was identified (van den Berg et al., 2003). We identified two polymorphic repeats [(GAAA)*n* and (GAAAA)*n*] in the intron of *5HTT* (Hong et al., 2006). The androgen receptor (*AR*) gene is related to human sexuality and personality (Rubinow and Schmidt, 1996; Jönsson et al., 2001). We have identified two poly-glutamine repeats (Q1 and Q2) in dogs (Maejima et al., 2005).

The use of dogs to prevent the smuggling of illegal drugs began in West Germany after World War II. In present-day Japan, approximately 100 dogs (mostly Labrador Retrievers) serve in this

capacity. In Japan, 60 candidate dogs are trained as drug detection dogs each year. After 1 month of familiarisation training during which dogs became accustomed to their working environment, candidate dogs are trained for an additional 3 months at a training centre to detect drugs. Dogs that pass are formally recognized as drug detection dogs (Narita Airport Customs Home Page: <http://www.narita-airport-customs.go.jp/>).

Given that only about 30% of dogs are successfully trained for this role, it would be desirable to develop a means of assessing aptitude for training at an early stage. If factors underlying aptitude for drug detection are better understood, it will be possible to better predict which dogs can be successfully trained; hence, reducing the burdens on trainers and costs. We sought to test several factors that may be related to successful training of dogs for drug detection, including behavioural traits and genotypes for 197 candidate dogs.

2. Materials and methods

2.1. Subjects

One hundred and ninety-seven Labrador Retrievers from Tokyo Customs Canine Training Center in Narita, Japan served in the present study. These dogs were borrowed directly from multiple breeders when the dogs were between 1 and 2 years of age. The breeders kept dogs in indoor kennels. In addition, breeders provided the dogs with basic socialization training that involved the dogs interacting with people and other dogs. Because sex data was not recorded by the training centre, at the time we genotyped the four candidate genes, we used the same DNA samples to determine sex by testing for the presence of the Y chromosome. There were 109 males, 81 females, and 7 of indeterminate sex.

Among males, 54 were castrated, 28 were not castrated, and castration status for 27 subjects was not provided. Among females, 23 were spayed, 38 were not spayed, and spay status for 20 subjects was unknown. Among subjects of indeterminate sex, three were neutered and four were not neutered.

2.2. Training

Behavioural training and evaluation was carried out between 2001 and 2005. Behavioural training for each subject lasted 4 months. The first month consisted of familiarisation training during which dogs became accustomed to their working environment, including people, stairs, and baggage conveyers for about 1 hour each day. During familiarisation training, trainers also played with dogs using a rolled towel (dummy). After the first 2 weeks of familiarisation training, trainers rated dogs on the seven behavioural traits (see Section 2.3.1) that would later be used to predict whether a candidate dog became qualified to work as a drug detection dog.

After familiarisation training, dogs were trained to detect drugs for 3 months. This again involved trainers playing with dogs using a dummy, but during drug detection training, drug scents were added to dummies. Dogs were then trained to search for dummies that had drug scents added to them. When dogs found dummies that had drug scents, trainers positively reinforced the dogs by playing with them, leading dogs to associate drug scents with these reinforcers. This procedure resulted in maintaining the dogs' desire to search for drug scents without the use of dummies. Finally, dogs were tested and classified as having passed or failed drug detection training.

2.3. Measures

2.3.1. Behavioural evaluation

After 2 weeks of familiarisation training, dogs were rated on seven traits. To determine whether dogs successfully completed training, the dogs were rated on four behavioural scales.

Ratings on the seven behavioural traits were based on each rater's subjective impression of the dog that had formed during familiarisation training. Ratings were not based on specific behavioural tests. Subjective ratings on simple adjectival descriptors have been used to reliably rate other nonhuman species, including dogs and there is considerable evidence for the predictive validity of these ratings (Jones and Gosling, 2005).

Three trainers rated each dog's standing on seven traits: *general activity* (amount of activity typically observed); *obedience training* (degree to which the dog obeys orders); *concentration* (degree of concentration during training); *affection demand* (degree of the desire to play with humans); *aggression toward dogs* (degree of aggression toward other dogs); *anxiety* (degree of anxiety displayed toward humans, objects, sounds, and so on); and *interest in target* (degree of interest in the dummy). Ratings were made on a 5-point scale in which a score of 1 indicated "very low" and 5 indicated "very high." Average scores of the different trainers were used to determine the score for each dog on each trait.

Passing status as drug detection dogs was determined by a single test during which they were assessed by two trainers. The trainers who evaluated the dogs' performance were not involved in the familiarisation training and did not rate dogs on the previously described seven traits.

For the test, dogs were evaluated on their ability to detect drug scents in baggage, cargo, and mail. On each item, trainers rated each dog's standing on drive for search (scores 3.5, 3.0, 1.5, and 0.5), sensitivity to drug scents (scores 2.0, 1.5, 1.0, and 0.5), interest in drug scents (scores 2.0, 1.5, 1.0, and 0.5), and reactivity to drug scents (scores 2.5, 2.0, 1.5, and 0.5). For a dog to be certified for drug detection, it had to receive a score greater than 7.0 by both raters.

2.3.2. Genotyping

DNA was extracted from the buccal mucous membranes of the dogs. The buccal cells were collected from each dog's cheek by cotton swabs. Then, cotton swabs were immediately washed out in 2 ml saline and preserved in a 90% ethanol solution. Total DNA from buccal cells was obtained by column purification method using DNA QIAamp Blood Kit (Qiagen, CA, USA). DNA samples were stored at 4 °C until analysis.

The genotyping methods of the eight polymorphic regions of four genes, *DRD4* exon1, *DRD4* intron2, *DRD4* exon3, *5HTR1A*, *5HTT* (GAAA)n, *5HTT* (GAAAA)n, *AR* Q1 and *AR* Q2 have been previously described (Niimi et al., 1999, 2001; Ito et al., 2004; Maejima et al., 2005; Nara et al., 2005; Hong et al., 2006; Koshimura et al., 2006). Briefly, DNA samples were amplified by PCR using the following primers which were designed based on the dogs' DNA sequence: D4e1F (5'-CGCCATGGGGAACCGCAG-3') and D4e1R (5'-CGGCTCACCTCGGAGTAGA-3') for *DRD4* exon1; D4e2F3 (5'-GCCATCAGCGTGGACAGGT-3') and D4e3R (5'-CGTCGTTGAGGCCGACAGCAC-3') for *DRD4* intron2; D4F (5'-TTCTTCCTACCC-TGCCCGCTCATG-3') and D4dogR (5'-CCGCGGGGGCTCTGCAGGGTCG-3') for *DRD4* exon3; d5H-TT-F (5'-AACGAAGAGAGCCAGTTCA-3') and d5HTT-Ra (5'-TTTCTTTTCTTTTCTATTTTCTTTC-3') for *5HTT* (GAAA)n; d5HTT-Fb (5'-GAAAGAAAATAGAAAAGAAAAGAAA-3') and d5HTT-R (5'-GGCCTCCCCTTCTTCATATT-3') for *5HTT* (GAAAA)n; Q1F (5'-CCGTGAGCGCAGCACCTCC-CGGTG-3') and Q1R (5'-AGGCTGACCGCTTGGGAAGGCTGC-3') for *AR* Q1; and Q2F (5'-GCCAG-CACCACCGGACGAGAATGA-3') and Q2R (5'-TAACTGTCCTTGGAGGAGGTGGAAGCA-3') for *AR* Q2. For exon 3 of *DRD4*, to facilitate the identification of alleles of the same length, we used a combination of D4F and D4dogBR (5'-TGGGCTGGGGGTGCCGTCC-3'), too.

We used 50 ng of DNA in 10 µl of reaction mixture containing 0.5 µM of each primer. The size of PCR products was estimated using the ABI3100 DNA sequencer and the GENESCAN software package (Perkin-Elmer, MA, USA). To identify the SNP of *5HTR1A*, we used an allele-specific PCR method. We used 50 ng of DNA in 10 µl of reaction mixture containing 0.5 µM of primers: 5HTR1A16F (5'-CCTTTGGCG-CTTTCTACATCC-3') and allele-specific primers 5HTR1A16RT (5'-CAGAGGCCCCCAGCCTT-3') or 5HTR1A16RG (5'-CAGAGGCCCCCAGCCTG-3'). A combination of 5HTR1A16F and 5HTR1A16RG amplified C allele, and that of 5HTR1A16F and 5HTR1A16RT amplified A allele. The products were then electrophoresed on 1.5% agarose gel to visualise the result of amplification.

To test for the presence of the Y chromosome, the same DNA samples were amplified by PCR using the following primers which were designed based on dogs' Y chromosome-specific sequences: 650-F

(5'-GTCCTGGGTTCTCGGGTTAGTGTTAG-3') and 650-R (5'-GTCCTGGGTTGAAGCCCTACATTG-3') for the 650 bp fragment, 990-F (5'-GTCCTGGGTTCTCCATTGTGTTCC-3'), and 990-R (5'-GTCCTGGGTTGCAGGGTTGGTTCA-3') for the 990 bp fragment (Olivier and Lust, 1998). We used 50 ng of DNA in 10 µl of reaction mixture containing 0.5 µM of each primer, and the products were then electrophoresed on 1.5% agarose gel to visualise the result of amplification.

2.4. Statistical analyses

2.4.1. Principal components analysis

Principal components analysis was carried out on the seven behavioural traits. Variances for the seven behavioural traits ranged from 0.543 (*obedience training*) to 1.001 (*interest in target*), suggesting that none of these variables should be excluded for low variances. Skewness ranged from absolute values of 0.038 (*concentration*) to 0.694 (*aggression toward dogs*) and kurtosis ranged from absolute values of 0.127 (*general activity*) to 0.713 (*aggression toward dogs*). These findings and visual inspection of the distributions indicated that the behavioural traits were close to be normally distributed. Thus, we used the raw behavioural trait scores in this analysis.

To determine how many components to extract we used parallel analysis (Horn, 1965; O'Connor, 2000). This technique involves comparing eigenvalues (a measure of components' variances) derived from the actual data to the 95th percentile of eigenvalues that would be expected under chance conditions. One then only extracts components which have eigenvalues that are greater than 1.00 (as eigenvalues less than or equal to 1.00 would indicate that a component had no more variance than a single variable) which exceed the eigenvalues expected under chance.

The first two principal components (2.325 and 1.291) had eigenvalues that were greater than expected under chance. Combined, these two components accounted for 51.66% of the total variance in the seven behavioural traits.

After extracting these two components we subjected them to varimax rotation. Varimax rotation is used to increase the interpretability of the components by maximizing the variance of each component. This is done by making the absolute high factor loadings as close to 1.00 as possible and the low factor loadings as close to 0 as possible.

The rotated factor structure is presented in Table 1. We defined salient loadings as absolute values that were greater than or equal to 0.400, as this is a standard convention and has been used in principal component analyses of similar trait measures (e.g., Weiss et al., 2006). All trait loadings on the first component were positive and included *general activity*, *obedience training*, *concentration*, *anxiety*, and *interest in target*. These loadings suggest that this component perhaps reflected a desire for or interest in the

Table 1
Factor loadings on the first two principal components for the seven behavioural traits of drug detection dogs

| Behavioral traits | Components | |
|--------------------------------|-----------------|-----------------|
| | Desire for Work | Distractibility |
| Concentration | 0.809 | 0.115 |
| Interest in target | 0.790 | −0.125 |
| General activity | 0.736 | 0.038 |
| Anxiety | 0.514 | −0.059 |
| Aggression toward dogs | −0.042 | 0.748 |
| Obedience training | 0.402 | −0.658 |
| Affection demand | 0.203 | 0.550 |
| Eigenvalue | 2.325 | 1.291 |
| Cumulative % of total variance | 32.692 | 51.657 |

Note: Absolute factor loadings greater than or equal to 0.400 were considered salient and indicated in boldface.

Table 2

Allele frequencies of eight polymorphic regions of *DRD4*, *5HTR1A*, *5HTT* and *AR* for drug detection dogs

| Gene | Region | Allele | Number | Frequency | | |
|---------------|-----------|-------------|--------|-----------|-----|-------|
| <i>DRD4</i> | exon1 | <i>S</i> | 166 | 0.421 | | |
| | | <i>L</i> | 228 | 0.579 | | |
| | intron2 | <i>P</i> | 222 | 0.563 | | |
| | | <i>Q</i> | 172 | 0.437 | | |
| | exon3 | <i>435</i> | 119 | 0.302 | | |
| | | <i>447a</i> | 273 | 0.693 | | |
| | | <i>447b</i> | 2 | 0.005 | | |
| <i>5HTR1A</i> | | <i>A</i> | 35 | 0.089 | | |
| | | <i>C</i> | 359 | 0.911 | | |
| <i>5HTT</i> | (GAAA)n | <i>10</i> | 10 | 0.025 | | |
| | | <i>11</i> | 14 | 0.036 | | |
| | | <i>12</i> | 34 | 0.086 | | |
| | | <i>13</i> | 20 | 0.051 | | |
| | | <i>14</i> | 139 | 0.353 | | |
| | | <i>15</i> | 170 | 0.431 | | |
| | | <i>16</i> | 2 | 0.005 | | |
| | | <i>17</i> | 5 | 0.013 | | |
| | (GAAAA)n | <i>5</i> | 4 | 0.010 | | |
| | | <i>6</i> | 125 | 0.317 | | |
| | | <i>9</i> | 5 | 0.013 | | |
| | | <i>10</i> | 48 | 0.122 | | |
| | | <i>11</i> | 24 | 0.061 | | |
| | | <i>12</i> | 185 | 0.470 | | |
| | | <i>13</i> | 3 | 0.008 | | |
| | | <i>AR</i> | Q1 | <i>10</i> | 96 | 0.354 |
| | | | | <i>11</i> | 175 | 0.646 |
| Q2 | <i>22</i> | | 37 | 0.137 | | |
| | <i>23</i> | | 215 | 0.793 | | |
| | <i>24</i> | | 9 | 0.033 | | |
| | <i>25</i> | | 10 | 0.037 | | |

work. The traits that loaded on the second component included *obedience training* (negative), *affection demand*, and *aggression toward dogs* and suggest that this component reflected distractibility.

We then, for each dog, created unit-weighted component scores in which a component score was defined by the sum of traits that had salient loadings. Thus, traits with non-salient loadings were assigned weights of 0, traits with salient and positive loadings were assigned weights of +1, and traits with salient and negative loadings were assigned weights of −1. While *obedience training* loaded onto both components, it was assigned a weight of 0 on Desire for Work and −1 on Distractibility, as it had a higher absolute loading on the latter component.

For ease of interpretability, component scores were converted into *T*-scores that have a mean of 50 and standard deviation of 10. Because neither the Desire for Work (skewness = 0.088; kurtosis = −0.101) or Distractibility (skewness = −0.471; kurtosis = 0.205) unit-weighted *T*-scores show much deviation from normality, these *T*-scores were used in all of the remaining analyses.

2.4.2. Sex, and neutering-status differences in Desire for Work and Distractibility

The general linear model (GLM) is a robust statistical model of which the analysis of variance is a special case. Sex differences or hormonal differences between neutered and non-neutered dogs might cause dogs to

differ in the mean levels of the Desire for Work and Distractibility component scores, so both were included as covariates in the analysis. For the 143 subjects for which sex and neutering status were known, we used a GLM with Type III Sums of Square to test whether sex, castration, or the Sex \times Neutering interaction independently influenced Desire for Work or Distractibility.

2.4.3. *Desire for Work and Distractibility as predictors of successful training*

We used logistic regression analysis to assess whether Desire for Work or Distractibility were related to whether a dog successfully completed training and became certified for drug detection work. Logistic regression analysis is a form of regression analysis used when one wishes to predict the odds of a binary outcome such as passing or failing with a series of predictor variables. Results are presented in terms of odds ratios or the increase in the likelihood of an outcome related to a single unit increase in a predictor variable. In the present study, of the 197 dogs, 60 passed and 137 failed training. Predictor variables included sex, neutering status, the Desire for Work *T*-score, and the Distractibility *T*-score. Because sex or neutering status was unknown for 54 dogs, the logistic regression analysis was based on the 143 (43 passing and 100 failing) dogs for which sex and neutering status was known.

We were also interested in whether there were mean-level differences in the Desire for Work and Distractibility between dogs that did and did not successfully complete training. Using all 197 dogs in the analysis, we compared mean levels of Desire for Work and Distractibility *T*-scores of dogs that did and did not pass training via a GLM.

2.4.4. *Cut-off point*

Based on Desire for Work *T*-scores, we examined the optimal cut-off point for selection of drug detection dog.

2.4.5. *Genetic predictors of Desire for Work and Distractibility*

Haplotypes were estimated using Arlequin version 2.000 (<http://www.lgb.unige.ch/arlequin/>). Genotyping was carried out for eight polymorphic regions of four genes: the exon 1, intron 2 and exon 3 regions of *DRD4*; *5HTT*; the (GAAA)*n* and (GAAAA)*n* regions of *5HTT*; and the Q1 and Q2 regions of *AR* (see Table 2). In addition, 15, 33, and 15 haplotypes were estimated in *DRD4*, *5HTT*, and *AR*, respectively. Based on haplotypes of *DRD4*, *5HTT*, and *AR* as well as the *5HTT* genotype, all 197 dogs were divided into two groups and the mean Desire for Work and Distractibility *T*-scores were compared between groups by one-way ANOVA. The division was done with or without alleles/haplotypes, haplotype *S:Q:447a* (exon 1:intron 2:exon 3) of *DRD4*, allele *A* of *5HTT*, haplotype *Long* [total repeat number of (GAAA)*n* and (GAAAA)*n* was above 27] of *5HTT* and haplotype *11:23* (Q1:Q2) of *AR* (Table 3).

3. Results

3.1. *Sex, and neutering-status differences in Desire for Work and Distractibility*

Males had higher scores ($M = 52.143$, $S.D. = 10.035$) in Desire for Work than females ($M = 49.735$, $S.D. = 10.803$), but this difference was not statistically significant (partial $\eta^2 = 0.011$, $F_{1,139} = 1.563$, $P > 0.05$). Neutered dogs ($M = 51.476$, $S.D. = 10.459$) had higher scores in Desire for Work than non-neutered dogs ($M = 50.916$, $S.D. = 10.421$), but this difference was also not statistically significant (partial $\eta^2 = 0.001$, $F_{1,139} = 0.150$, $P > 0.05$). The Sex \times Neutering interaction was not significant (partial $\eta^2 < 0.001$, $F_{1,139} = 0.068$, $P > 0.05$).

Females ($M = 52.562$, $S.D. = 8.512$) scored slightly higher than males ($M = 50.251$, $S.D. = 9.386$) in Distractibility, but this difference was not statistically significant (partial $\eta^2 = 0.016$, $F_{1,139} = 2.274$, $P > 0.05$). Neutered ($M = 48.421$, $S.D. = 10.191$) dogs had significantly lower Distractibility scores than non-neutered ($M = 52.798$, $S.D. = 8.017$) dogs

Table 3
Comparison of the mean Desire for Work and Distractibility scores of groups divided by haplotypes or genotypes for drug detection dogs

| Gene | Group | Genotype/haplotype | n | Desire for Work | | | Distractibility | | |
|--------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----------------|-------|-------|-----------------|-------|-------|
| | | | | Mean ± S.D. | F | P | Mean ± S.D. | F | P |
| DRD4 | S:Q:447a (+) | S:Q:435/S:Q:447a, S:Q:447a/S:Q:447a, S:Q:447a/L:P:435, S:Q:447a/L:P:447a, S:Q:447a/L:P:447b, S:Q:447a/L:Q:435, S:Q:447a/L:Q:447a | 128 | 48.99 ± 9.60 | 3.781 | 0.053 | 50.50 ± 9.60 | 0.928 | 0.337 |
| | S:Q:447a (–) | S:P:447a/L:P:435, S:P:447a/L:P:447a, L:P:435/L:P:435, L:P:435/L:P:447a, L:P:435/L:Q:447a, L:P:447a/L:P:447a, L:P:447a/L:P:447b, L:P:447a/L:Q:447a | 69 | 51.87 ± 10.53 | | | 49.07 ± 10.70 | | |
| 5HTR1A | A (+) | A/A, A/C | 33 | 48.27 ± 9.99 | 1.183 | 0.278 | 50.31 ± 9.47 | 0.038 | 0.845 |
| | A (–) | C/C | 164 | 50.35 ± 10.00 | | | 49.94 ± 10.13 | | |
| 5HTT | Long | 16/27, 17/27, 19/27, 20/27, 21/27, 22/27, 23/27, 23/28, 24/27, 25/27, 26/27, 27/27, 27/28 | 116 | 49.03 ± 10.46 | 2.672 | 0.104 | 51.41 ± 9.72 | 5.746 | 0.017 |
| | Short | 16/20, 16/21, 16/22, 16/26, 17/20, 17/22, 17/26, 20/20, 20/22, 20/23, 20/25, 20/26, 21/22, 21/26, 22/22, 22/23, 22/25, 22/26, 23/25, 25/25 | 81 | 51.39 ± 9.19 | | | 47.98 ± 10.11 | | |
| AR | 11*23 (+) | 11*23/–, 10*22/11*23, 10*23/11*23, 10*24/11*23, 10*25/11*23, 11*23/11*23 | 151 | 50.01 ± 10.03 | 0.002 | 0.960 | 50.12 ± 9.78 | 0.017 | 0.898 |
| | 11*23 (–) | 10*22/–, 10*23/–, 10*24/–, 10*25/–, 10*22/10*22, 10*22/10*23, 10*23/10*23, 10*25/10*25, 11*22/11*22 | 45 | 50.10 ± 10.10 | | | 49.90 ± 10.71 | | |

(partial $\eta^2 = 0.058$, $F_{1,139} = 8.495$, $P < 0.01$). The Sex \times Neutering interaction was not significant (partial $\eta^2 = 0.001$, $F_{1,139} = 0.087$, $P > 0.05$).

3.2. *Desire for Work and Distractibility as predictors of successful training*

Even after controlling for the nonsignificant effects of sex (odds ratio = 2.140; 95% CI = 0.872–5.249; $P > 0.05$) and being neutered versus non-neutered (odds ratio = 1.744; 95% CI = 0.717–4.241; $P > 0.05$), there was a significant effect of Desire for Work (odds ratio = 1.144; 95% CI = 1.085–1.206; $P < 0.001$). The effect of Distractibility was not significant. The odds ratio of this significant effect indicates that in this sample each Desire for Work *T*-score unit was related to a 14.4% increase in the likelihood that a dog would successfully complete training. Distractibility was not related to whether a dog successfully completed training (odds ratio = 1.021; 95% CI = 0.973–1.073; $P > 0.05$).

Comparison of the mean Desire for Work and Distractibility *T*-scores of dogs that did and did not successfully complete training revealed that dogs that passed had significantly higher (partial $\eta^2 = 0.213$, $F_{1,195} = 52.627$, $P < 0.001$) Desire for Work scores ($M = 56.95$; S.D. = 8.30) than those that did not ($M = 46.96$; S.D. = 9.14). Dogs that passed had lower Distractibility scores ($M = 48.42$; S.D. = 10.45) than dogs that did not pass ($M = 50.69$; S.D. = 9.75), but the difference was not significant (partial $\eta^2 = 0.011$, $F_{1,195} = 2.164$, $P > 0.05$).

3.3. *Cut-off point*

Since 93.3% (56/60) of dogs that passed and 53.3% (73/137) of dogs that failed had Desire for Work *T*-scores of 45 (equivalent to a raw score of about 13) or higher, by using this as a cut-off point, training centres will be able to reject about half of the dogs that are unlikely to complete training prior to the 3 months of training. Overall, the examination pass rate among dogs scoring 45 or higher on Desire for Work was 43.4% (56/129).

3.4. *Genetic predictors of behavioural factors*

Accordingly, in *5HTT* the *Long* haplotype group showed higher Distractibility score ($F_{1,195} = 5.746$, $P < 0.05$). However, after correcting for multiple tests with Bonferroni's correction, the difference was not statistically significant ($P > 0.0063$ or $0.05/8$). No relationship between haplotypes/genotypes and passing status was detected (data not shown).

4. Discussion

We evaluated factors related to the aptitude of dogs that were trained in drug detection. Dogs were rated on seven behavioural traits that reflected two principal components: Desire for Work and Distractibility.

Sex was not related to Desire for Work or Distractibility in our study. Previous studies suggested that sex is related to behavioural traits. Wilsson and Sundgren (1997) reported that male Labrador Retrievers scored significantly higher than females in 'defense drive' and 'hardiness' whereas females scored significantly higher than males on 'ability to cooperate'. Male working dogs are more commonly used in search work than females. However, females scored closer to ideal levels on 'level of aggression towards dogs'. Thus, if good individuals are

selected, females can be trained to become proficient search dogs (Svartberg, 2002; Rooney and Bradshaw, 2004).

We found that neutering reduced Distractibility. The effect of neutering on dog behaviour has been previously noted. Hart and Eckstein (1997) reported that sexually dimorphic behavioural patterns are reduced or eliminated in males by castration and reported that roaming was reduced in 90% of dogs by castration. While it is not identical to distractibility and no studies have examined the relationship between distractibility and roaming, it is possible that these two behaviours are related as both involve a lack of focus.

Much like our findings that Desire for Work was related to an increased likelihood that a dog would successfully complete training, Wilsson and Sundgren (1997) reported that police dogs scored markedly higher in the characteristics ‘courage’, ‘hardiness’, ‘prey drive’, and ‘defense drive’ than public German Shepherds. Therefore, traits related to Desire for Work might be a necessary aptitude for working dogs. Our analysis recommends a raw score cut-off point of Desire for Work of approximately 13. Using this criterion will enable trainers of candidate Labrador Retrievers to reject about half of dogs that would be inappropriate for drug detection work.

It is not clear whether the behavioural traits assessed in this study would predict success in training different breeds of dog or training dogs for different jobs, and it is likely that different mean scores may indicate trainability in different breeds. However, these results are encouraging and recommend studies assessing how generalisable these results are.

In the present study dogs were also genotyped for genes that have been associated with human personality dimensions. At most we only found a weak relationship between the *5HTT* haplotype and Distractibility scores. *Aggression toward dogs* had a salient loading on this component, and, hence, this finding was somewhat consistent with findings that *5HTT* was related to anxiety or aggression-related behavioural traits in humans (Beitchman et al., 2006). As such, the *5HTT* genotype might be a useful marker of aggression-related traits in dogs.

While we only examined Labrador Retrievers, allele frequencies of *DRD4* and *5HTT* polymorphic regions vary greatly among different breeds and some research suggests that these different allele frequencies are related to breed-specific behavioural traits (Ito et al., 2004; Hong et al., 2006). While we did not detect a significant relationship between genotypes and whether dogs successfully completed training, the existence of several alleles within our sample suggests that dogs might be further bred for behavioural traits related to successful training as drug detection dogs.

Future research should concentrate on increasing the sample size and the number of alleles examined or conducting genome scans to see whether any particular genotypes underlie behavioural factors such as Desire for Work. In addition, the result that traits are related to successful training suggests that it might be worth including additional subjective and behavioural measures to better understand the behavioural characteristics.

5. Conclusion

In this study we demonstrated that behavioural traits indicating Desire for Work were important predictors of whether dogs could be trained for drug detection work. We examined cut-off point for selection of dogs for drug detection training. Using this cut-off point would allow training centres to reject approximately half of the inappropriate dogs before training and raise the examination pass rate. Several studies have reported on dog temperament and personality; however, these studies have not explored the genotypic bases of these traits. In the present study

we examined polymorphic regions of genes that have been related to human personality dimensions. Haplotypes or genotypes were not related to whether dogs passed, but there was a weak relationship between Distractibility and the *5HTT* haplotype. We recommend further studies exploring the use of behavioural traits and genotypes to assess whether dogs are suitable for certain training programs or work.

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